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Optimizing Propagation of Ceanothus americanus L., (New Jersey Tea), Corylus cornuta Marsh. (beaked filbert), Lonicera canadensis Bartr. (American fly honeysuckle), and Viburnum acerifolium L. (mapleleaf viburnum) by Softwood Stem Cuttings

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Chapter 1: Literature Review

There is increased interest in using native plants for landscaping as alternatives to exotic species, some of which are invasive (Ruchala et al., 2002; Brand, 2008; Zadegan et al., 2008; Lubell et al., 2010). The Connecticut Natural Resource Conservation Service (2010d) defines a native plant as a plant that is a part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem. An invasive plant is defined as both non-native and able to establish on many sites, grow quickly, and spread to the point of disrupting plant communities or ecosystems.

Native plants are not invasive and they create the look and feel of a natural landscape. Consumer studies have shown that natural landscapes are increasing in popularity and consumers are willing to pay premium prices for an attractive garden featuring native plants (Zadegan et al., 2008; McCoy, 2011). The interest in gardening with natives is not only for their ornamental qualities and novelty, but also to take advantage of their adaptation to local climates and resistance to environmental stresses (Schrader and Graves, 2000; Stanton et al., 2010). Native plants are well adapted to the New England climate since they grow naturally in New England (Hightshoe, 1988). Native plant landscapes often require less irrigation, seasonal protection, and mechanical control of diseases and pests (Dyas, 1975).

Some native shrubs are commonly used in landscaping such as *Ilex verticillata*, (winterberry holly), *Cornus alba* (red twig dogwood), *Clethra alnifolia* (summersweet clethra), and *Kalmia latifolia* (mountain laurel). There is a desire among nursery growers and landscape architects to increase the palette of native plants available for landscaping (Brand, 2008; Ruchala et al., 2002; Stanton et al., 2010; Brzuszek and Harkess, 2009).

Four under-utilized native shrubs with ornamental potential are *Ceanothus americanus L.*, *(*New Jersey tea*)*, *Corylus cornuta* Marsh. (beaked filbert), *Lonicera canadensis* Bartr. (American fly honeysuckle), and *Viburnum acerifolium* L. (mapleleaf viburnum). The wide adaptability of these species to natural settings makes them prime candidates for development as native plants for landscapes. Propagation protocols must be optimized if these plants are to reach a level of production where they are readily available to landscapers and homeowners. Therefore the objective of this work was to evaluate the influence of indole-3-butyric acid (IBA) concentration, cutting collection timing, and transplanting timing on propagation success of softwood stem cuttings of *C. americanus*, *C. cornuta*, *L. canadensis*, and *V. acerifolium*.

***Ceanothus americanus* L.**

Ceanothus americanus is a deciduous subshrub to shrub in the Rhamnaceae family (Coladonato, 1993; Fross and Wilken, 2006; Wynia, 2010). *Ceanothus* is a large genus consisting of approximately 64 species. *Ceanothus americanus* was the first species in the genus to be named (Fross, 2006). Its close relatives east of the Mississippi are *Ceanothus herbaceus* (formerly *Ceanothus ovatus*) and *Ceanothus sanguineus* (Helm, 1906; Fross and Wilken, 2006; Dirr, 2009). There are three recognized varieties of *C. americanus*, *intermedius*, *americanus* and *pitcheri* (Coladonato, 1993; Fross and Wilkens, 2006). The common names of *C. americanus* are New Jersey tea, redroot (an ancient Greek name referring to the plants red roots) (Magee and Ahles, 1999), Indian tea, wild lilac, wild snowball, mountain sweet, snowbrush, and soapbloom (Wynia, 2010; Fross and Wilkens, 2006; Dirr, 2009; Cullina, 2002). The leaves were used by American colonists during the Revolutionary war as a tea substitute although they do not contain any caffeine. The leaves were used for tea by Native American tribes of the Missouri River region and the roots were used for cooking fuel as a wood substitute on buffalo hunting trips (Wynia, 2010). The root provides a strong astringent with 8 percent tannin. The roots were recently discovered to contain a blood-clotting agent.

Ceanothus americanus extends from Quebec, Canada south along the eastern seaboard to Florida, west to Texas, then north to Minnesota into Manitoba, Canada (Coladonato, 1993; Wynia, 2010). *Ceanothus americanus* has been observed in every state in New England as well as every county in Connecticut (Magee and Ahles, 1999). It is listed as endangered in Illinois and threatened in Maine (Coladonato, 1993; Wynia, 2010). This species is cold hardy to United States Department of Agriculture hardiness zones 3a (Anonymous, 2012).

New Jersey tea grows on coarse to medium sandy soils in mesic-dry to dry sites that contain well draining soil with pH between 4.5 and 6.0 (Hightshoe, 1988; Magee and Ahles, 1999; Dirr, 2009; Wynia, 2010). It grows in dry open woods, brushy pastures, rocky upland hillsides, and mixed deciduous forest borders. It prefers full sun but exhibits intermediate shade tolerance. It is very intolerant of flooding. Associate trees of *C. americanus* are oaks, hickories, and persimmon. Associate shrubs include wintergreen, hazelnut, sumac, Carolina rose, common deerberry, and gray dogwood (Hightshoe, 1988; Coladonato, 1993).

Ceanothus americanus is an erect shrub with many slender upright shoots that form an open crown (Coladonato, 1993; Fross and Wilken, 2006; Dirr, 2009). Plants have a slow to medium growth rate and reach 0.5 to 1 m in height (1.5 to 3.5 feet) and 0.9 to 1.5m (3 to 5 feet) in width. Leaves are alternate, simple, ovate to obovate and are dark green in summer turning yellow to tan in fall. Leaves are pubescent or nearly glabrous on the lower surface with 3 prominent veins from the leaf base. Leaves are from 5 to 7.6 cm (2 to 3 inches) long and 2 to 5 cm (0.8 to 2 inches) wide and the petioles are 0.4 to 1.1 cm (0.2 to 0.4 inches) long (Fross and Wilken, 2006; Dirr, 2009).

The flowers of *C. americanus* are perfect, borne in 1 to 2 inch corymbose panicles in the upper leaf axils of the current year's branchlets but not at the stem terminal (Holm, 1906; Fross and Wilken, 2006; Dirr, 2009). Flowers are sweetly fragrant and white to cream colored. There are 5 sepals, 5 hatchet shaped petals, a large pistil, and 5 stamens. The flowering period, which lasts about 1 month, generally occurs from June to July in Connecticut.

The fruit of *C. americanus* is a 3 lobed drupe that is brown to dark brown and 0.3 cm to 0.5 cm (1/5 to 1/4 inch) wide. Fruit separates into 3 compartments when mature. Seeds are smooth coated, elliptical, dark reddish brown and 0.2 to 0.3 cm (0.08 to 0.12 inches). Seeds mature in August to September (Fross and Wilken, 2006; Dirr, 2009; Wynia, 2010).

Ceanothus americanus has dark red shallow, fibrous, lateral roots near the surface of the soil and deeper underground are thick, woody, roots from 6 to 8 inches in diameter. Root systems can withstand fire and support nitrogen fixing bacteria (Holm, 1906; Hightshoe, 1988; Coladonato, 1993; Dirr, 2009). While the plant is described as difficult to transplant it is an extremely adaptable plant with few physiological, insect, or disease problems. Powdery mildew and leaf spots may occur. *Ceanothus americanus* is resistant to drought, heat, and salt but is reportedly sensitive to soil compaction (Hightshoe, 1988; Dirr, 2009). Owing to its drought tolerance, fire resistance, and nitrogen fixing abilities it is considered an early to mid-seral species that can rapidly colonize a disturbed area and is an important plant for habitat restoration projects (Coladonato, 1993).

Ceanothus americanus is of intermediate wildlife value for upland gamebirds, songbirds, and small mammals (Hightshoe, 1988). Stomach records indicate use by at least 4 species of birds including bobwhite and wild turkey (VanDersal, 1939). Deer will browse twigs and foliage (Hightshoe, 1988). This plant is of major importance for 5 rare and endangered specialist insect species (Schweitzer et al., 2011; Wagner personal communication, 2012).

Ceanothus americanus as well as most *Ceanothus* species exhibit complex seed dormancy, which makes it difficult to propagate by seed (Dirr, 2009; Stewart, 2010). In nature *C. americanus* reproduces by seed and sprouting following a fire event (Coladonato, 1993). Stewart and McGary (2010) found that a combination of 60 days of cold-moist and following exposure to boiling water enhanced germination by 48%. Dirr and Heuser (1987) suggest that softwood cuttings of *C. americanus* and *C. ovatus* taken spring to fall and placed in mist will have 100% rooting and use of rooting hormone will decrease time to rooting and improve rooting. Kujawski and Hayward (2002) report that softwood cuttings can be taken in June and July, trimmed to 6” leaving one pair of leaves, dipped in 1:10 solution of rooting hormone, stuck in flats with perlite, and put into mist for several weeks until rooting occurred. A general recommendation for most *Ceanothus* species suggested by Cullina (2002) is that softwood cuttings taken from vigorous new growth in early summer root well when treated with 1,000 ppm IBA and stuck in flats with 1:3 peat-perlite.

Currently *C. americanus* is available to consumers from various sources. Containers range in size from 4 inch pots to 3 gallon pots with prices ranging from $4.95 to $24.00.

***Corylus cornuta* Marsh.**

Corylus cornuta is a woody shrub in the Betulaceae family (Hsuing, 1951). *Corylus* is a relatively small genus consisting of approximately fifteen species that are native to North America, Europe and Asia. *Corylus cornuta* is closely related to *C. cornuta* var. *californica*, (California hazelnut), *Corylus americana* (American filbert), and to *Corylus avellana* (European filbert or European hazelnut). Marshall, in 1785, was the first to name and describe the species *Corylus cornuta*. The common names of *C. cornuta* are beaked filbert, beaked hazelnut, and beaked hazel and they refer to the bracts over the nut which fuse at the tip, forming an extended, tubular “beak-like” structure.

The most northern range of *C. cornuta* extends along the eastern seaboard from Alabama and Georgia (Appalachian) to Newfoundland then westward through Canada and the Great Lake states and onto northeast British Columbia (Fryer, 2007; Hsuing, 1951; Anonymous, 2010a; Barbour and Brinkman, 1974). *Corylus cornuta* has been observed in every county in New England (Magee and Ahles, 1999). It is rare in Illinois and extirpated in Ohio (Fryer, 2007). This species is cold hardy to United States Department of Agriculture hardiness zone 3a (Anonymous, 2010a).

Beaked filbert is naturally found growing on moist to dry sites with moderately well to very well draining soil and soil pH between 5.3 and 6.1 (Hightshoe, 1988; Stearns, 1974). It has been sighted in dry open woods, edges of woods, brushy pastures, fence rows, rocky hillsides and banks of quick flowing streams. It prefers sun but tolerates shade and is intolerant of flooding. Associate plants that grow in the same habitat with *C. cornuta* are trees including paper birch, quaking aspen, northern pin oak, jack/red/eastern white pines, red maple, and shrubs including American filbert, dwarf bush honeysuckle, lowbush blueberry, mapleleaf viburnum, and witch hazel.

Corylus cornuta is a dense, multi-stemmed, shrub with upright spreading branches (Hsiung, 1951). It grows from 2 to 4 m in height (6 to 12 feet) with equal spread, has a slow to medium growth rate, and may form colonial thickets. *Corylus cornuta* has simple, alternate, double toothed leaves that are yellow-green in spring, medium green in summer, and yellow in fall. Leaves are slightly tomentose to dull smooth on the upper surface and soft tomentose beneath. The size of the leaves range from 2.5 to 12.7 cm (1 to 5 inches) long and 2 to 7.6 cm (0.8 to 3.0 inches) wide and the petioles are 2 to 3 cm (0.3 to 1.2 inches) long.

The flowers of *C. cornuta* are monoecious, not equipped with perianth and bloom before the leaves emerge. Male flowers are purplish brown drooping catkins and are 2.5 cm to 5 cm (1 to 2 inches) long. Male catkins, in numbers of 1 to 4, form at the end of the twig of the previous season or in the axil of a leaf. Male catkins appear as early as the middle of June of the previous year and develop very slowly reaching about 0.6 cm to 1.3 cm (1/4 to 1/2 inch) long by the winter. The female flowers are 3 cm (1/8 in) long, bright red in color and appear in mid March to early April (Hsiung, 1951). *C. cornuta* is wind pollinated (Fryer, 2007)

The fruit of *C. cornuta* is a brown oval nut that is 0.6 cm to 1.3 cm (1/4 to 1/2 inch) in diameter. It is borne in clusters of 1 to 6. Each nut is tightly enclosed in a bristly elongated beak-like husk. The beak like husk is actually a leafy involucre that is covered with whitish, acid secreting bristles (Hsuing, 1951).

The fruit, edible by both humans and animals, is rich in protein and healthy fat (Van Dersal, 1939; Stearns, 1974). It is an important food source for many mammals and some ground and song birds. The stomach records show it to be a food source for ruffed grouse, bobwhite, sharp-tailed grouse, and prairie chicken. It composes 2.7% of the winter food of the northern sharp-tailed grouse in Quebec and Ontario. The nut of *Corylus cornuta* is the eighth most preferred winter food of white-tailed deer. It is also used by blue jay, turkey, moose, southwestern chipmunk, eastern chipmunk, and squirrels.

Corylus cornuta winter buds and spring catkins are a valuable protein source for ruffed grouse and American woodcock (Stearns, 1974). The leaves are the primary food source for the larval stage of the turquoise hairstreak butterfly, (*Erora laeta)* (Cullina, 2002). The leaves are high in nitrogen, calcium, and magnesium so as plants shed their leaves in fall they feed nearby plants and are an integral part of nutrient cycling in the forest (Tappeiner and Alm, 1975; Fryer, 2007).

Corylus cornuta has a shallow and lateral fibrous root system that forms suckers (Hsuing, 1951; Hightshoe, 1988). It transplants well and has few physiological, insect, or disease problems. Eastern filbert blight can be an occasional problem. *C. cornuta* is tolerant of drought, heat, and soil compaction but is reportedly intolerant of salt and pollution (Hightshoe, 1988).

There is limited information available on propagation of *C. cornuta.* Dirr and Heuser (1987) suggest propagating by seeds sown in fall or provided 3 months cold stratification. The closely related species *C. cornuta* var. *californica* can be propagated by cuttings collected and stuck between July and November (O'Neil, 2009). This method resulted in 50% rooting success after 50 days under mist. No fully scientific studies with *C. cornuta* have been done to determine the most efficient propagation method for commercial nursery production.

Currently *C. cornuta* is available to consumers from limited sources in sizes ranging from 1 to 2 foot plants for $4.64 to 1 gallon containers for $18 (Engel, 2010). Pierson Nursery in Biddeford, ME offers different size containers ranging in price from $6.50 to $12.00 (Anonymous, 2010e). Plants purchased by the Lubell lab from Pierson in 2010 were mislabeled and were actually *C. americana*.

***Lonicera canadensis* Bartr.**

Lonicera canadensis (American fly honeysuckle), is a member of the Caprifoliaceae family and is the most widely spread native honeysuckle in the Northeast (Jackson, 1974; Anonymous, 2012; Anonymous, 2010b). It is a loosely branched deciduous shrub, reaching 3 to 6 feet tall at maturity. It has opposite, simple, narrow-ovate to elliptical leaves that are 1-3 inches long. Leaves are smooth except for ciliate or extremely fine hairs on the leaf edges. Leaves are bright green above and a bit paler green below. The leaf petiole is hairy. Twigs are slender, smooth, and reddish grey to brown with solid pith. The buds are small and pointed. Bark is reddish grey and is finely peeling and shredding on larger stems.

The native range of *L. canadensis* extends along the Atlantic seaboard from New Brunswick, Canada in the north to Georgia in the south, with the exception of South Carolina. It extends west to Ontario in Canada and Iowa in the United States

(Anonymous, 2010c). *Lonicera canadensis* has been observed in every New England state except for Rhode Island. It is not found in New Haven County in Connecticut and four counties in southeastern Massachusetts, including all areas of Cape Cod (Magee and Ahles, 1999). *Lonicera canadensis* is listed as extirpated in Indiana, an endangered species in New Jersey and Maryland, and a species of special concern in Tennessee (Anonymous, 2010c).

Lonicera canadensis typically occupies dry, rocky woods but does not thrive in dry, sandy soils (Jackson, 1974). *L. canadensis* is drought and heat tolerant, salt and compaction resistant and transplants well (Hightshoe, 1988). Moist, rich soils with abundant organic matter are preferred. It grows in both acid and alkaline soils (Jackson, 1974; Hightshoe, 1988). Best growth occurs in full sun but *L. canadensis* is shade-tolerant and persists even under thick cover.

Lonicera canadensis is often found in northern hardwood or mixed hardwood/coniferous forest in New England (Jackson, 1974). Associate plants include serviceberry, witch-hazel, beaked hazel, viburnums, red maple, sugar maple, eastern hemlock, red spruce, balsam fir, aspen, birches, and spirea among others (Hightshoe, 1988). American honeysuckle competes well with its associates, but unlike its shrub relatives *Lonicera morrowii* (Morrow's honeysuckle) and *Lonicera tatarica* (Tatarian honeysuckle), it is not aggressive or invasive (Jackson, 1974).

Lonicera canadensis is one of the earliest shrubs to leaf out and flower (Jackson, 1974). It blooms in April and May with monoecious, yellowish-green to straw-colored, 2 cm (0.8 inches) long, bell or funnel shaped flowers. Flowers occur in pairs in the leaf axils. The flowers are followed by reddish orange, fleshy, berries that are elongated with a tapering point. Berries are 0.8 cm (1/3 inch) long, contain several seeds, and fully ripen in July to August. *L. canadensis* grown in the shade have sharply reduced flowering and fruit production (Jackson, 1974). Plants do not exhibit major damage from pests, disease or browse problems (Anonymous, 2012). Small birds eat the fruit as it ripens.

Although it is suggested that all *Lonicera* species are easy to moderately easy to propagate by stem cuttings (Anonymous, 2012; Hartmann et al., 2002; Cullina, 2002), there is no specific information about *L. canadensis* cutting propagation in the literature. Commercial availability of *L. canadensis* is very limited. The Connecticut Native Tree and Shrub Availability list identified 10 nurseries in CT offering *L. canadensis* (Picone, 2005) however this information could not be verified by the online inventories of these nurseries.

***Viburnum acerifolium* L.**

Viburnum acerifolium (mapleleaf viburnum), is a member of the Caprifoliaceae family. It is a shrub or subshrub, with a loose habit reaching 1 to 2 m (4 to 6 feet tall) and 1.5 m (4 feet) wide at maturity (Dirr, 2009; Anonymous, 2012; Coladonato, 1993; Hightshoe, 1988). Through root suckering it often forms large colonies or thickets. Leaves are opposite, simple, suborbicular to ovate 3-lobed with coarse teeth that are 7.5 to 12.5 cm (3 to 5 inches) long, dark green and slightly pubescent above and more densely pubescent below with dark dots. Twigs are brown and pubescent when young turning glabrous when mature. The buds are green with red highlights, small and narrow. Bark is smooth with prominent lenticels and the old stems are scaly and purplish brown.

The native range of *V. acerifolium* extends along the Atlantic seaboard from northern New Brunswick, Canada in the north to Florida in the south, west to Texas, and north through Minnesota to Ontario, Canada. This species is hardy to United States Department of Agriculture hardiness zone 4 to 8 (Anonymous, 2012; Dirr, 2009). *Viburnum acerifolium* has been observed in every New England state and is found in every county in Connecticut (Magee and Ahles, 1999).

Viburnum acerifolium typically occupies mesic to dry woods in moderate to well drained sandy loam soil (Dirr, 2009; Glenn, 2012; Hightshoe, 1988; Rollins, 1974). *Viburnum acerifolium* is shade and drought tolerant as it mostly grows as an understory plant. *Viburnum acerifolium* is very adaptable being found growing on dry south-facing slopes and ridge tops but also occurring in north-facing moist floodplain forest (Coladonato, 1993; Hightshoe, 1988; Rollins, 1974). It tolerates acid soil pH ranging from 5.1 to 6.0. Plants are intolerant of flooding (Dirr, 2009; Hightshoe, 1988; Rollins, 1974).

Viburnum acerifolium is dominant or codominant member of the shrub layer in the deciduous beech-maple forest. This plant community includes beaked filbert, common spicebush, witch-hazel, mountain laurel, lowbush blueberry, white ash, sugar maple, white oak, tuliptree, sweet birch, and butternut among others (Coladonato, 1993; Hightshoe, 1988; Rollins, 1974). *V. acerifolium* adapts well to a variety of habitats due to its shade and acid soil tolerance as well as drought resistance (Coladonato, 1993; Rollins, 1974). Due to its attractive flowers and fruits *V. acerifolium* has been cultivated since 1736 (Coladonato, 1993).

Viburnum acerifolium leaves emerge in New England in mid-May and plants bloom in mid to late June (Dirr, 2009; Brand, 2001; Coladonato, 1993; Hightshoe, 1988). Plants are monoecious. The blooms are small, creamy white, and held in flat-topped cymes 7.5 cm (3 inches) across (Hightshoe, 1988; Rollins, 1974). The flowers develop into oval red fleshy drupes containing a thin flattened stone. The drupe is 0.8 cm (1/3 inch) long, and ripens in mid-August first turning blue then black. Plants do not exhibit major damage from pests, disease or deer browse problems however the viburnum leaf beetle may be a concern in urban landscapes and nurseries (Anonymous, 2012). Game birds, many species of songbirds, and mammals eat the mature fruit.

Viburnum acerifolium is reported to root well from cuttings taken June to August (Dirr, 2009; Fahmey et al., 2012). *Viburnum acerifolium* is available commercially to retail consumers in sizes and prices ranging from a quart pot for $12.00 to 3 gallon pots for $35.00.

Woody Plant Softwood Stem Cutting Propagation

In the nursery trade most deciduous shrub species are vegetatively propagated by softwood stem cuttings. Softwood stem cuttings are taken in the spring to early summer when the new shoots are still pliable but can be easily snapped. The birch (Betulaceae), honeysuckle, (Caprifoliaceae), and buckthorn families (Rhamnaceae) are all propagated by softwood cuttings (Dirr and Heuser, 1987). Cutting propagation is useful for obtaining marketable sized plants in a short amount of time, maintaining genetic integrity, and for species that are not easily propagated by seed (Hartmann et al., 2002). The nursery industry standard for stem cutting propagation success is 50% rooting, (Bishop and Nelson, 1980) however most nursery propagators desire greater percentages. In addition to percent rooting, other measures of propagation success are number of roots per cutting and root length (Pijut and Moore, 2002; Condon and Blazich, 2003; Rosier et al., 2004; Griffin, 2008; Southworth and Dirr, 2009). Some factors that can influence softwood stem cutting success are hormone concentration, timing of cuttings, and transplanting timing.

The application of exogenous hormone on the basal portion of softwood stem cuttings has a demonstrated influence on rooting success which is generally species dependent. Studies conducted with *Rhamnus caroliniana*, *Alnus maritima*, and *Amelanchier alnifolia*, looked at application of indole-3-butryic acid (IBA) in talc formulation at various concentrations ranging from 1000 to 8000 ppm IBA compared to an untreated control (Graves, 2002; Schrader and Graves, 2000; Bishop and Nelson, 1980). For both *R. caroliniana* and *A. maritima* IBA application increased percent rooting, number of roots and root length. *R. caroliniana* rooting percentage with either 3000 or 8000 ppm IBA was greater than 75% while the untreated control was less than 10%. *A. maritima* percent rooting was 68% at 8000 ppm IBA, 57% at 3000 ppm IBA, and 39% for the control. Rooting of *A. alnifolia* was not improved by application of IBA in talc.

In a study with *Viburnum rufidulum* cuttings treated with 1000, 3000, or 8000 ppm IBA in talc were compared with cuttings treated with 3000, 6000, or 9000 ppm potassium (K) salt IBA (K-IBA) dissolved in distilled water (Griffin, 2008). IBA in talc did not increase percent rooting over the untreated control (28%). K-IBA in distilled water had greater rooting percentage than control with 87% for 6000 ppm, 77% for 9000 ppm, and 60% for 3000 ppm. Nair et al. (2008) evaluated *Stewartia pseudocamellia* cuttings treated with 8000 ppm IBA talc, 8000 ppm K-IBA in distilled water, and a combination of 3000 ppm IBA in talc and 5000 ppm K-IBA in distilled water all compared to an untreated control. The best rooting percentage was achieved with the combination treatment of 3000 ppm talc and 5000 ppm K-IBA in distilled water (94%), followed by 8000 ppm K-IBA in distilled water (90%), 8000 ppm IBA in talc (72%), and untreated control (53%).

In studies with *Ulmus parvifolia*, *Amelanchier laevis*, and *Lindera umbellata* cuttings were treated with K-IBA in distilled water at various concentrations ranging from 2500 to 20,000 ppm (Griffin and Schroeder, 2004; Still and Zanon, 1991; Condon and Blazich, 2003). For the three species K-IBA application increased rooting success over the untreated control. For *U. parvifolia* greatest percent rooting was 15,000 and 20,000 ppm K-IBA (97%). The greatest rooting percent for *A. laevis* was 5000 ppm K-IBA (88%) and for *L. umbellata* it was 7500 ppm K-IBA (73%). In a study with *C. harringtonia* IBA application did not significantly impact rooting. Rooting percentage of cuttings treated with 10,000 ppm K-IBA in distilled water (68%) was not significantly different from untreated control (78%) (Southworth and Dirr, 1996).

Polar solvents are frequently used as an IBA carrier. Cullina, 2002 discussed the increased absorption of IBA in solvents as compared with talc. Since IBA in talc is less soluble the uptake is incomplete resulting in less tissue burning however it leads to lower rooting percentage on certain species. IBA is very soluble in solvents and the cuttings are dipped in the dissolved solution for a greater length of time then with IBA in talc. These increases in solubility and length of exposure to IBA lead to more tissue absorption.

A study was conducted with *Rhamnus alnifolia* and *Rhamnus lanceolata* comparing 3000 and 8000 ppm IBA in talc, and 3000 and 8000 ppm IBA in acetone, with an untreated control (Sharma and Graves, 2005). Interestingly, IBA in talc promoted rooting while IBA in acetone inhibited rooting. Rooting percentage was 85% for both

3000 and 8000 ppm IBA in talc and was 15% and 0% for 3000 and 8000 ppm IBA in acetone solution, respectively. Untreated control rooted at 75%.

Studies with a *Corylus americana* x *Corylus avellana* hybrid and *Alnus rubra* evaluated IBA dissolved in ethanol at various concentrations ranging from 750 to 8000 ppm IBA (Ercisli and Read, 2001; Radwan et al., 1989). For the *Corylus* hybrid hormone application was required for rooting with the greatest percent rooting with 1500 ppm IBA (95%). For *A. rubra* rooting hormone application improved rooting percentage over the control; however control rooted at 58%. The best hormone treatment of 80% rooting was a 10-second dip in 2000 or 4000 ppm IBA. It was found that 8000 ppm IBA delayed and reduced rooting compared with the lower concentrations. Crisofori et al. (2009) found *Corylus avellana* cuttings treated with 1000 and 2000 mg kg^{-1} IBA dissolved in diethyl ether had greater rooting than an untreated control. The rooting percentages were 21%, 13%, and 0.7% for 2000, 1000 mg kg^{-1} IBA, and control, respectively. Upon further study the authors found that by adding 1600 ppm putrescine to the 1000 mg kg^{-1} IBA treatment rooting percentage could be improved to 32%.

Studies with *Juglans cinerea* and *Abies fraseri* compared two different auxin compounds at various concentrations (Pijut and Moore, 2002; Rosier et al., 2004). With *J. cinerea* cuttings were treated with 34 and 74 mM IBA in 70% ethanol and 29 and 62 mM K-IBA in water and compared with an untreated control. Hormone application improved rooting success over the control for both auxin types. Greatest rooting percent was at 62 mM K-IBA (77%) and 74 mM IBA (88%), the highest concentrations studied for each auxin type. For *Abies fraseri* auxin concentration had a significant impact on percent rooting, number of roots, and root length. In this study cuttings were treated with

7 concentrations ranging from 1 to 64 mM of both IBA and NAA dissolved in 50% isopropyl alcohol/50% water. Percent rooting increased as auxin concentration increased up 5 mM (99%) at which point percent rooting decreased steadily.

In addition to hormone concentration the timing of stem cuttings may have a major impact on rooting success. Timing of cuttings is not based on a chronological calendar but on the cuttings physiological state (Dirr and Heuser, 1987). The growth stage of a plant at which the cuttings are taken often determines the outcome of vegetative propagation as measured by the rooting percentage, root number, and root length (Still and Zanon 1991). There are several indicators of stem cutting status including firmness of the wood and timing of terminal bud development. In the spring to early summer or when shoots are emerging with active, new, undeveloped terminal tissue and the stems are pliable but can be easily snapped is considered the softwood stage for stem cuttings (Dirr and Heuser, 1987; Hartmann et al., 2002).

Three cutting timings were studied for the species *Amelanchier laevis, Ulmus parvifolia*, a *Corylus americana* x *Corylus avellana* hybrid, and *Corylus avellana* (Still and Zanon, 1991; Griffin and Schroeder, 2004; Ercisli and Read, 2001; Cristofori et al., 2009). For *A. laevis* cuttings were made in May, June, and July. June cuttings had the greatest rooting percentage and number of roots per cutting followed by May cuttings and July cuttings. Rooting percentages were 76% in May, 82% in June, and 59% in July. Cuttings taken in June, July, and August were evaluated for *U. parvifolia* and *C. americana* and *C. avellana* hybrid. For both species June cuttings performed the best having the greatest rooting percentage (97% and 95% respectively) and number of roots per cutting. However, July cuttings of *U. parvifolia* had better survival rates than the other cutting timing treatments. Cristofori et al. (2009) compared propagation success of cuttings of *C. avellana* taken in June, July, and September. For this species September cuttings had the highest rooting percentage (16%) followed by June (14%) and July (5%).

Studies with *Viburnum rufidulum*, *Alnus maritima*, and *Lindera umbellata* compared cuttings made in June with cuttings made in August (Griffin, 2008; Schrader and Graves, 2000; Condon and Blazich, 2003). For *V. rufidulum* and *A. maritima* June cuttings had greater rooting percentages (87% and 72% respectively) than August cuttings (49% and 8% respectively). Additionally, June cuttings of *V. rufidulum* produced more roots and June cuttings of *A. maritima* produced longer roots. For *L. umbellata* August cuttings performed much better than June cuttings with August cuttings having 73% rooting and June 5% rooting.

Bishop and Nelson (1980) evaluated cuttings of *Amelanchier alnifolia* over a small time frame. Cuttings were made in mid-June and late June/early July during 1975 and 1976. Interestingly the small difference in time had significant impact on rooting success. Cuttings taken in late June/early July had 71-75% rooting and cuttings in mid June had 51-55% rooting. For *A. alnifolia* the later timing of July 2, 1975 had highest rooting percentage (75%) followed by June 26, 1976 (71%), June 20, 1975 (59%), and June 10, 1976 (51%). A *Juglans cinerea* study comparing two timings in June and July was done in 1999 and repeated in 2000, but only the 2000 results were significant (Pijut and Moore, 2002). In 2000 the greatest percent rooting was on June 12 (88%) and June 23 (75%) followed by July 19 (58%) then July 7 (47%).

Douglas (1966) evaluated several cutting timings across May and early June for 7 *Vaccinium corymbosum* cultivars. For all cultivars late May (May 29) cuttings had highest percent rooting 90-100%. The authors suggest that at that time shoots were in an inactive growth phase which improved rooting ability.

Transplanting timing of rooted cuttings has been shown to be a critical factor for propagation success of several species (Dirr and Heuser, 1987). Overwintering can be a problem with *Hydrangea quercifolia*, *Hydrangea anomala* subsp *petiolaris,* and *Viburnum acerifolium*. Some *Stewartia* species are difficult to propagate showing lack of overwintering success with newly rooted cuttings (Fordham, 1982; Dirr and Heuser, 1987). For these species Dirr and Heuser (1987) recommend it is best to not disturb rooted cuttings and to repot rooted cuttings following overwintering when new growth begins to emerge in the spring. With *Hamamelis* and *Fothergilla* Fordham (1976) and Dirr and Heuser (1987) recommend cuttings be rooted in pots, cell packs, or 2.25 by 2.25 by 5 inch bottomless rose-type pots to avoid root disturbance upon transplanting.

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Chapter 2: Effect of Softwood Cutting Timing on Propagation of *Ceanothus americanus, Corylus cornuta, Lonicera canadensis,* and *Viburnum acerifolium*

The timing of stem cutting collection can impact rooting success of woody plant species. The objective of this study was to determine if timing of cuttings impacts propagation success of *Ceanothus americanus*, *Corylus cornuta*, *Lonicera canadensis*, and *Viburnum acerifolium*.

Materials and Methods

The softwood stem cuttings were taken from wild populations in 2012 during the second week of June, July, and August. Plant material was collected from wild stands in Tolland and Windham counties in Connecticut and Worcester County in Massachusetts (Table 2.1). Plant material was collected from current year's growth in early morning when shoots were turgid. Plant material was contained in plastic bags in a chilled ice chest for transport to the University of Connecticut Plant Science Research and Education Facility greenhouse in Storrs, CT where it was processed into uniform cuttings. Cuttings were 12.7 to 17.8 cm (5 to 7 inches) long for *Ceanothus americanus* and 10.1 to 12.7 cm (4 to 5 inches) for *Corylus cornuta* and *Lonicera canadensis*.

In 2011 a separate study was conducted to determine if there was a difference in rooting success between single-node and two-node cuttings of *V. acerifolium*. Single-node cuttings were from current season's growth on flowering shoots and two-node cuttings were from current season's growth on non-flowering vegetative shoots. Two-node cuttings had significantly greater rooting percent, number of roots per cutting, and root length, therefore two-node cuttings were used in the 2012 timing study. *Viburnum acerifolium* two-node cuttings were 10.1 to 15.2 cm (4 to 6 inches) long.

After wild collected plant material was processed into uniform length cuttings a fresh cut was made on the basal portion of each stem and the basal 1.5 cm (0.59 inches) of the cutting was wounded on two sides with a sharp knife through to the cambium. Wounding causes an increase in endogenous auxin and other metabolic activity at the wound site, which stimulates healing, speeds growth of roots, and improves root quality (Toenyan et al., 2012; Nair and Zhang, 2010). Wounding also increases cell division, permits greater absorption of exogenous hormone, and on certain species decreases the inhibition of adventitious root growth by lignification (Hartmann and Kester, 2002; Maynard and Bassuk, 1996). Cuttings were treated with 3000 ppm (0.3%) IBA (indole-3-butyric acid) in talc (Hormodin, OHP, Inc., Mainland, PA) prior to sticking. Excess hormone was removed by tapping the base of the cutting on a firm surface.

The experimental unit was a Connecticut (CT) pack (K & C Plastics 6.4 cm x 12.7 cm x 16.5 cm) with ten cuttings containing a potting medium composed of 2:1:1 Canadian sphagnum peat moss (Conrad Fafard, Inc., Agawam, MA) horticultural grade perlite (super coarse; Whittemore Co. Inc., Lawrence, MA) horticultural grade vermiculite (A3 medium; Whittemore Co. Inc., Lawrence, MA). Finished units were placed on a polyhouse bench equipped with intermittent mist set to spray for fifteen-second duration every 6 minutes in a randomized complete block design with 7 replications (210 cuttings per species). Once a complete block of experimental units was completed it was set under mist before beginning the next block. Cuttings were harvested eight weeks after sticking and percent rooting, average total number of roots per cutting, and average root length of three longest roots per cutting was measured. Only roots greater than or equal to 0.5 cm in length were evaluated, and a cutting having 1 or more roots was classified as rooted. Data were subjected to analysis of variance (PROC MIXED) and mean separation using Fisher's least significant difference test ($P \leq 0.05$) using SAS for Windows Version 9.2 (SAS Institute).

Results

Ceanothus americanus cuttings taken in June had 57% rooting success which was significantly greater than cuttings taken in July and August (Table 2.2). Rooting percentage decreased progressively as cutting collection date got later in the season. Rooting percentage for July was 47% and for August was 34% and these results were not significantly different. Furthermore the number of roots and the root length was two times greater for June cuttings than July and August cuttings.

Rooting percentage of June cuttings of *Lonicera canadensis* was 49% and significantly greater than July and August cuttings (Table 2.2). The number of roots produced and root length was also greater for June cuttings than July cuttings but the differences were not significant.

For both *Corylus cornuta* and *Viburnum acerifolium* the percent rooting was not significantly different for June, July, and August cuttings (Table 2.2). Over all timing treatments the rooting percentage for *C. cornuta* ranged from 86-91% and for *V. acerifolium* ranged from 97-100%. For both species the number of roots produced was not significantly different across timing treatments. For *C. cornuta* the root length of June cuttings was significantly greater than July cuttings and for *V. acerifolium* root length of July cuttings was significantly greater than June and August cuttings. These findings for root length do not support the trends for rooting percentage and are difficult to explain. They may be an artifact of too few replications or too few roots measured per cutting.

Discussion

The influence of timing of cuttings on propagation success is species dependent. Propagation success of *Ceanothus americanus* and *Lonicera canadensis*, two of the four native shrub species evaluated in this study, was strongly influenced by timing. June was the best timing treatment for taking cuttings of *C. americanus* and *L. canadensis*. June cuttings had the greatest rooting percentage, number of roots and root length compared with July and August cuttings. One important characteristic for a plant species to be considered a viable nursery crop is that it can be propagated with a minimum success rate of 50% (Bishop and Nelson, 1980; Still and Zanon, 1991). June cuttings of *C. americanus* demonstrated 57% rooting. June cuttings of *L. canadensis* had a rooting percentage of 49%, which was much greater than the 10% for July and 20% for August. This finding for *L. canadensis* in combination with the observation that *L. canadensis* is one of the earliest shrubs to leaf out in the spring suggests that it is possible that *L. canadensis* rooting success can be increased by taking cuttings earlier than June. The findings for *C. americanus* and *L. canadensis* are similar to results reported for *Amelanchier laevis*, *Alnus maritima*, and *Viburnum rufidulum* (Still and Zanon, 1991; Schrader and Graves, 2000; Griffin, 2008) in which cuttings taken in June or earlier were more successful than cuttings taken later in the season.

Propagation success for the other two native species studied, *Corylus cornuta* and *Viburnum acerifolium*, was similar across all three timings and the rooting percentages for these species were much greater than those observed for *Ceanothus americana* and *Lonicera canadensis*. *Ilex verticillata* is a popular and widely grown native shrub crop that is propagated by stem cuttings with 80% rooting success. In this study both *C.*

cornuta and *V. acerifolium* had rooting success greater than 80% at all timings, indicating that *C. cornuta* and *V. acerifolium* have the potential to be successful new nursery crops. These findings are similar to the results for *Ulmus parvifolia*, *Aronia arbutifolia*, and *Cephalanthus occidentalis* where cuttings achieved 80% or greater rooting success at multiple timings (Griffin and Schroeder, 2004; Dehgan et al., 1989).

Table 2.1. Locations for timing study 2012 with softwood stem cuttings of *Ceanothus americanus*, *Corylus cornuta*, *Lonicera canadensis*, and *Viburnum acerifolium*.

Species	Collection Date	Town	State
Ceanothus americanus	14 June	Ashford	Connecticut
	12 July	Mansfield	Connecticut
	9 August	Ashford	Connecticut
Corylus cornuta	10 June	Willington	Connecticut
	8 July		
	5 August		
Lonicera canadensis	12 June	Petersham	Massachusetts
	10 July		
	7 August		
Viburnum acerifolium	10 June	Willington	Connecticut
	8 July		
	5 August		

Table 2.2. Percent rooting, number of roots per cutting, and root length of *Ceanothus americanus, Corylus cornuta, Lonicera canadensis,* and *Viburnum acerifolium* softwood stem cuttings collected in June, July, and August 2012.

Species and cutting date	Percent rooting	No. roots	Root length (cm)[z]
Ceanothus americanus			
June 14	57.1a[y]	5.1a	5.7a
July 12	47.1ab	2.7b	2.1b
August 9	34.3b	2.6b	2.7b
Corylus cornuta			
June 10	91.4a	4.1a	9.7a
July 8	85.7a	5.1a	6.7b
August 5	88.6a	4.9a	8.1ab
Lonicera canadensis			
June 12	48.6a	6.1a	4.7a
July 10	10.0b	4.9a	3.3a
August 7	20.0b	3.0a	3.4a
Viburnum acerifolium			
June 10	97.1a	15.4a	6.6b
July 8	97.1a	20.0a	7.9a
August 5	100.0a	19.0a	6.4b

[z] Root length is calculated by averaging the three longest roots.
[y] Mean separation within column, within species, according to Fisher's least significant difference $P \leq 0.05$.

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Chapter 3: Effect of indole-3-butyric acid (IBA) Rooting Hormone Concentration on Softwood Cuttings of *Ceanothus americanus, Corylus cornuta, Lonicera canadensis,* and *Viburnum acerifolium*

In woody plant stem propagation the application of exogenous rooting hormone is used to improve rooting success. There are demonstrated results showing variation in rooting success with hormone application among different plant species. It is essential for nursery propagators to understand the optimum rate at which to apply rooting hormone to obtain a marketable plant in the shortest amount of time. The objective of this study was to determine which concentration of indole-3-butyric acid (IBA) in talc applied to the basal portion of softwood stem cuttings was optimal for nursery production of four native woody plant species *Ceanothus americanus*, *Corylus cornuta*, *Lonicera canadensis*, and *Viburnum acerifolium*.

Materials and Methods

Softwood stem cuttings were taken during the second week of July in 2011 and 2012 from wild plant populations (Table 3.1). In 2011 and 2012 *Corylus cornuta* and *Viburnum acerifolium* were collected in Tolland County, CT. In 2012 *Ceanothus americanus* was collected in Windham County, CT and *Lonicera canadensis* was collected in Lincoln County, ME. Plant material was collected from current year's growth in early morning when shoots were turgid. Plant material was contained in plastic bags in a chilled ice chest for transport to the University of Connecticut Plant Science Research and Education Facility greenhouse in Storrs, CT where it was processed into uniform cuttings.

Procedures for plant material collection, handling, and cutting preparation for all species were similar to those used in the timing study (Chapter 2). For each species as plant material was removed from the bag and processed into cuttings it was randomly distributed among the four hormone concentration treatments. In 2011 single-node, 10.1 to 12.7 cm (4 to 5 inches), cuttings of *V. acerifolium* were made. Two-node cuttings of *V. acerifolium* were used in 2012 study.

Cuttings were dipped in 1000, 3000, or 8000 ppm (0.1, 0.3, or 0.8%) IBA in talc and an untreated control was also prepared. Experimental units were as described for the timing study and 7 replications were used. 280 cuttings were stuck per species over the 4 treatments. The media used and mist facility and conditions were the same as for the timing study. Data collection and statistical analysis was as described for the timing study.

Results

For *Lonicera canadensis* rooting percent ranged from 34% to 41% across treatments and treatments were not significantly different (Table 3.2). The greatest percent rooting was at 8000 ppm IBA. Number of roots and root length were not significantly different between treatments. Percent rooting for *Ceanothus americanus* was greatest at 3000 ppm IBA however there was no significant difference between treatments (Table 3.2). Among treatments rooting percent ranged from 34% to 48% which was similar to the range observed for *L. canadensis*. The greatest number of roots was 3.6 for 8000 ppm IBA and this was not significantly different from 3000 ppm IBA. The 3000 ppm IBA treatment had significantly more roots than the control. Root length was greatest at 8000 ppm IBA, but was not significantly different from the other treatments.

The hormone concentration study for *Corylus cornuta* and *Viburnum acerifolium* was conducted twice, first in 2011 and again in 2012 (Table 3.2). Similar trends were observed for *C. cornuta* in both years. Rooting percentage ranged from 64% to 81% in 2011 and from 74% to 86% in 2012. In both years, percent rooting increased as hormone concentration increased from 0 to 8000 ppm IBA. The greatest number of roots was achieved with 8000 ppm IBA in both years however, 8000 and 3000 treatments were not significantly different. In 2011 the root length was greater for cuttings treated with 1000, 3000, or 8000 ppm IBA compared to cuttings treated with no hormone. In 2012, number of roots was significantly greater at 8000 ppm IBA than the other treatments, which were not significantly different from each other.

A pilot study conducted concurrently in 2011 with the hormone concentration study indicated that two-node cuttings of *Viburnum acerifolium* rooted significantly better than single-node cuttings. In the pilot study (n=60) the two-node cuttings achieved 93% rooting while single-node cuttings had 53% rooting. Furthermore, the number of roots and root length were greater for two-node cuttings. In the 2011 hormone concentration study single-node cuttings were used, but based on the pilot study, two-node cuttings were used in 2012 in an attempt to identify the optimal cutting type and hormone concentration. In 2011 the greatest percent rooting was 80% at 3000 and 8000 ppm IBA and in 2012 all treatments rooted at 100% except 3000 ppm IBA which had 97% rooting. In 2011 percent rooting, number of roots and root length increased as hormone concentration increased from 0 to 8000 ppm IBA. For all measured parameters

3000 and 8000 ppm IBA treatments were significantly greater than no hormone control. In 2012 percent rooting, number of roots and root length did not differ significantly among treatments.

Discussion

In this study, propagation success was greater for *Corylus cornuta* and *Viburnum acerifolium* than *Ceanothus americanus* and *Lonicera canadensis*. Reduced success for *C. americanus* and *L. canadensis* may be due to the fact that cuttings were taken in July and a more optimal time for taking cuttings is June, according to the timing study (Chapter 2). Cullina (2002) reports moderate success with most *Ceanothus* species using 1000 ppm IBA. Griffin (2008) found that IBA in talc did not induce rooting of *Viburnum rufidulum* but 90-100% rooting success was attained with IBA in distilled water. It is possible that propagation success of *Ceanothus americanus* and *Lonicera canadensis* may be improved using different IBA carriers such as distilled water or ethanol.

Dirr and Heuser (1987) report that hormone application is essential for rooting of *Corylus* species. In this study, *C. cornuta* cuttings not treated with hormone rooted at 64% to 78%, depending on the year. The optimal hormone concentration rate for *Corylus cornuta* and *Viburnum acerifolium* was 3000 ppm IBA. This rate was also optimal for *Amelanchier alnifolia*, *Rhamnus alnifolia*, *Rhamnus lanceolata*, *Rhamnus caroliniana*, and *Alnus maritima* (Harris, 1961; Sharma and Graves, 2005; Graves, 2002, Schrader and Graves, 2000).

The results of this study indicate that with *Viburnum acerifolium* two-node cuttings yield greater propagation success than single-node cuttings, however single-node cuttings treated with 3000 or 8000 ppm IBA also produced around 80% rooting which may be acceptable given that single-node cuttings will more efficiently use cutting material. Cullina (2002) reports that all *Viburnum*, with the exception of *V. lantanoides*, are fairly easy to root. Cullina (2002) further reports for *Viburnum acerifolium* that non-flowering sucker shoots, with a minimum of two-nodes and treated with 1000 to 2000 ppm IBA root well.

One possible reason why two-node *V. acerifolium* cuttings rooted better than single-node was that two-node lacked flower buds and single-node did not. Studies of *Rhododendron*, *Camellia*, *Coleus*, *Vaccinium*, and *Taxus* have shown that the presence of flower buds on cuttings reduces rooting (Adams and Roberts, 1965). Furthermore, with *Rhododendron* the removal of flower buds from cuttings did not improve rooting compared to straight vegetative shoots (Adams and Roberts, 1965). It has been postulated that flower presence reduces the production of hormones important for rooting. Another possible cause for better rooting of two-node *V. acerifolium* compared to single-node is that two-node cuttings had greater amounts of endogenous auxin which benefits rooting. Endogenous auxin is produced in buds (Hartmann and Kester, 2002) and two-node cuttings had twice as many buds present as single-node cuttings.

Table 3.1.Study year, collection date, and location for hormone concentration study with softwood stem cuttings of *Ceanothus americanus, Corylus cornuta, Lonicera canadensis*, and *Viburnum acerifolium*.

Species	Collection Date	Town	State
2011			
Corylus cornuta	18 July	Willington	Connecticut
Viburnum acerifolium	18 July	Willington	Connecticut
2012			
Ceanothus americanus	12 July	Mansfield	Connecticut
Corylus cornuta	8 July	Willington	Connecticut
Lonicera canadensis	19 July	Damariscotta	Maine
Viburnum acerifolium	8 July	Willington	Connecticut

Table 3.2. Percent rooting, number of roots, and root length of softwood cuttings taken in 2011 and 2012 of *Ceanothus americanus*, *Corylus cornuta*, *Lonicera canadensis*, and *Viburnum acerifolium* treated with 0, 1000, 3000, or 8000 ppm indole-3-butyric acid (IBA) in talc formulation.

Species and IBA concentration	Percent rooting		No. roots		Root length (cm)[z]	
	2011	2012	2011	2012	2011	2012
Ceanothus americanus						
no IBA	-	34.3a[y]	-	2.3b	-	3.5a
1000 ppm IBA	-	40.0a	-	2.0b	-	3.1a
3000 ppm IBA	-	47.1a	-	2.7ab	-	2.1a
8000 ppm IBA	-	38.6a	-	3.6a	-	4.6a
Corylus cornuta						
no IBA	64.0a	78.6a	3.0c	3.4c	8.6b	6.7b
1000 ppm IBA	63.7a	74.3a	4.0bc	3.9bc	9.4ab	6.6b
3000 ppm IBA	81.3a	85.7a	4.6ab	5.1ab	9.9ab	6.7b
8000 ppm IBA	75.8a	84.3a	5.4a	6.0a	10.9a	8.7a
Lonicera canadensis						
no IBA	-	34.3a	-	7.8a	-	7.4a
1000 ppm IBA	-	27.1a	-	6.7a	-	6.6a
3000 ppm IBA	-	31.4a	-	6.3a	-	7.4a
8000 ppm IBA	-	41.4a	-	5.6a	-	6.5a
Viburnum acerifolium[x]						
no IBA	53.4b	100.0a	5.0b	21.9a	3.7b	7.9a
1000 ppm IBA	65.7ab	100.0a	6.7ab	19.9a	4.6ab	7.7a
3000 ppm IBA	80.0a	97.1a	8.3a	20.0a	4.9a	7.9a
8000 ppm IBA	78.6a	100.0a	9.4a	20.9a	5.3a	7.6a

[z] Root length is average of three longest roots

[y] Mean separation within column, within species, according to Fisher's least significant difference test $P \leq 0.05$.

[x] 2011 cuttings were one node (10.1-12.7 cm) in length and 2012 cuttings were two node (10.1-15.2 cm) in length.

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Chapter 4: Effect of Transplant Timing on Overwintering Performance of Softwood Cuttings of *Corylus cornuta* and *Viburnum acerifolium*

Some woody shrub species do not overwinter well following fall transplanting of rooted cuttings. It has been shown for some members of the genus *Amelanchier, Fothergilla*, *Hamamelis*, *Hydrangea*, and *Viburnum* that overwintering performance can be improved by postponing transplanting of rooted cuttings until spring following rooting (Bishop and Nelson, 1980; Fordham, 1976; Dirr and Heuser, 1987). The objective of this study was to compare overwintering survival of fall and spring transplanted rooted cuttings of *Corylus cornuta* and *Viburnum acerifolium*.

Materials and Methods

Plant material for preparing cuttings was collected from wild populations in Willington, Connecticut (Tolland County) during the third week of July 2011. Procedures for plant material collection, handling, and cutting preparation were similar to the timing study in Chapter 2. *Viburnum acerifolium* cuttings were made using non-flowering shoots and each cutting had two-nodes. Before sticking, cuttings were treated with 3000 ppm IBA in talc. There were ten cuttings per experimental unit and twelve replications for a total of 120 cuttings of *C. cornuta* and 120 cuttings of *V. acerifolium*. Propagation media and mist conditions were similar to the timing study in Chapter 2.

On 14 September 2011, 8 weeks after cuttings were initially stuck, rooted cuttings from half of the experimental units per species were transplanted. Rooted *Viburnum acerifolium* cuttings were transplanted into 2.25 inch Kord Traditional square pots (Myers Industries, Inc, Akron, OH) and *Corylus cornuta* rooted cuttings were transplanted into 4.5 inch Jumbo Jr. pots (Belden Plastics, St. Paul, MN). The media used for transplanting was 4:2:1 bark:peat:sand mix. Recently potted containers and the remaining undisturbed units were overwintered in a minimally heated polyhouse. On 19 April 2012, twenty-six weeks after cuttings were initially stuck, the remaining undisturbed units were transplanted following the same procedures as described above. Overwintering survival for all treatments was determined by the presence of bud break and leaf emergence in spring 2012. On 31 July 2012 the height and width (measured twice at right angles) was recorded for surviving plants.

Results and Discussion

For both *Corylus cornuta* and *Viburnum acerifolium* the number of surviving rooted cuttings was greater for spring transplanting than for fall transplanting (Table 4.1). Furthermore, percent survival for spring transplants was nearly double percent survival for the fall transplants. Clearly it is advantageous to leave cuttings undisturbed and transplant in the spring. It has also been shown with several other genera including *Acer*, *Hamamelis*, *Stewartia*, and *Viburnum*, that spring transplanting is better than fall transplanting (Fordham, 1982; Dirr and Heuser, 1987). One year old *Corylus cornuta* plants from cuttings were 23-26 centimeters tall and 17-20 centimeters wide. One year old *Viburnum acerifolium* plants from cuttings were 19 centimeters tall and 18 centimeters wide.

Table 4.1. Percent survival and one year old plant height and width of cuttings of *Corylus cornuta* and *Viburnum acerifolium* taken in July 2011.

Transplant season	*n*	Percent survival	One year old plants	
			Height in July 2012 (cm)	Width in July 2012 (cm)
Corylus cornuta				
Fall	17	53	25.8	19.9
Spring	24	92	23.3	17.1
Viburnum acerifolium				
Fall	48	56	19.4	17.5
Spring	31	100	19.1	18.3

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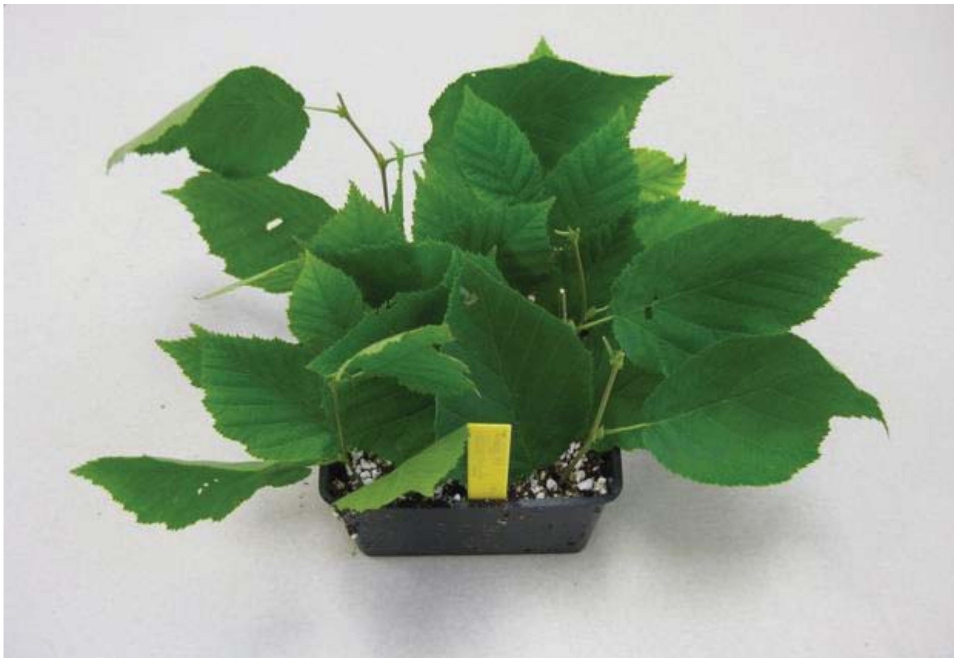
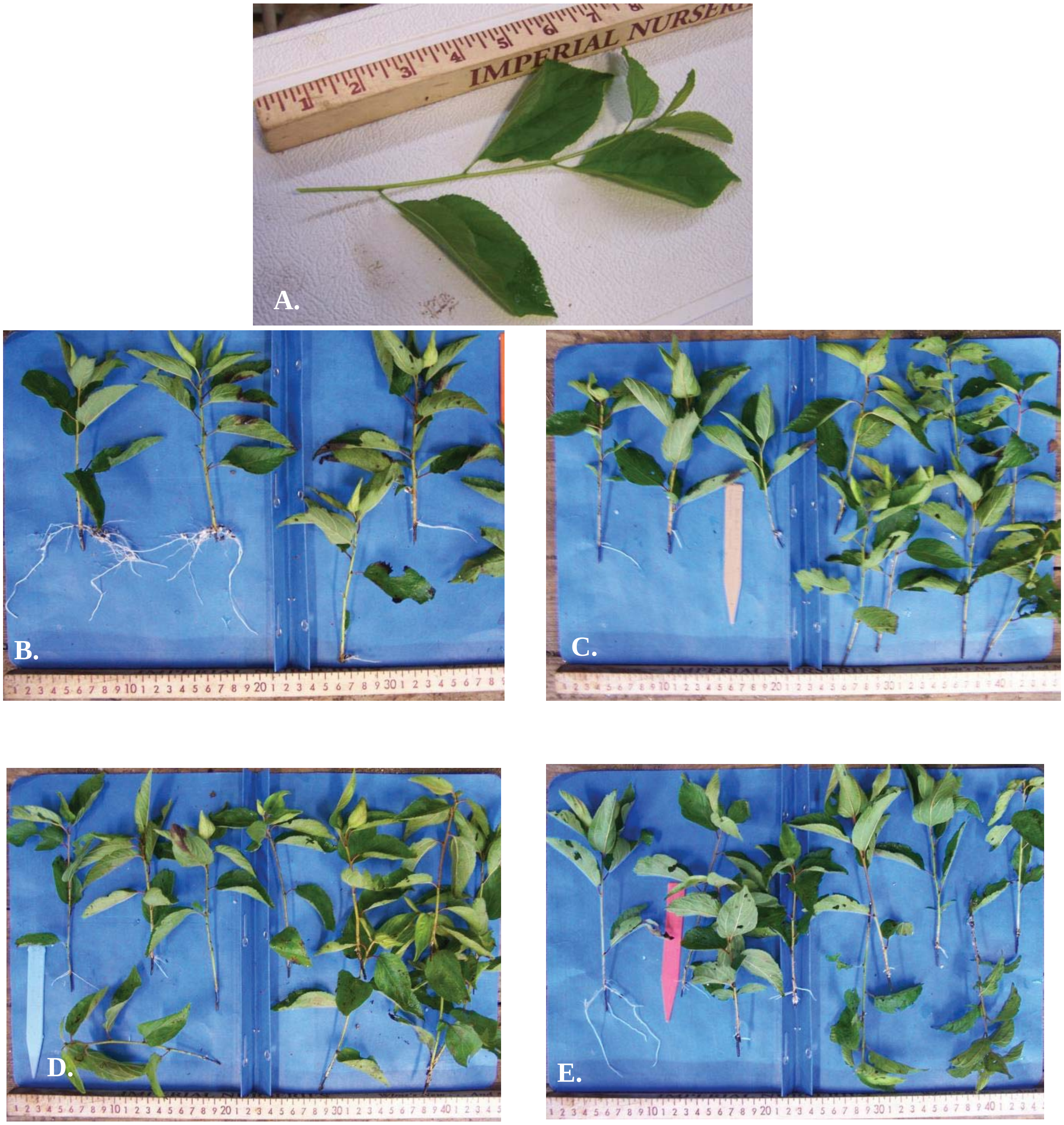
Appendix A



A ten cutting experimental unit of *Corylus cornuta*.

Appendix B



A) *Ceanothus americanus* cutting. B-E) 2012 cuttings at time of harvest for hormone concentration study with B) no hormone, C) 1000 ppm IBA, D) 3000 ppm IBA, and E) 8000 ppm IBA.

Appendix C

A) *Corylus cornuta* cutting. B-E) 2012 cuttings at time of harvest for hormone concentration study with B) no hormone, C) 1000 ppm IBA, D) 3000 ppm IBA, and E) 8000 ppm IBA.

Appendix D

A) *Lonicera canadensis* cutting. B-E) 2012 cuttings at time of harvest for hormone concentration study with B) no hormone control, C) 1000 ppm IBA, D) 3000 ppm IBA, and E) 8000 ppm IBA.

Appendix E

Viburnum acerifolium single-node cuttings.

Viburnum acerifolium single-node (left) and two-node (right).

Densely rooted *Viburnum acerifolium* cutting.

Appendix F

Viburnum acerifolium 2012 cuttings at time of harvest for hormone concentration study with A) no hormone, B) 1000 ppm IBA, C) 3000 ppm IBA, and D) 8000 ppm IBA.

Appendix G

One year old *Corylus cornuta* plants rooted from cuttings taken 2011 (July 2012).

Appendix H

One year old *Viburnum acerifolium* plants rooted from cuttings taken 2011 (July 2012).